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COLUMN FLOTATION RESEARCH (MANITOBA MDA)

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Summary

In early 1986 a research project was initiated to study the effect of column flotation in the Ruttan zinc circuit. This project was partially funded through an agreement with CANMET and the Manitoba MDA. A 36" diameter by 43' high flotation column was installed and tested on various flows in the zinc cleaning circuit. Initial test work produced erratic results due to oversized equipment and control problems. The project was recommissioned in 1989 and test work repeated after redesigning the column feed and tails discharge systems. The research indicated that the zinc concentrate could be upgraded by 4 units to 55% zinc, while maintaining the same zinc recovery as the existing circuit. Scale up using the test data showed that this could be achieved by replacing the zinc final cleaner cells with a 7 foot diameter flotation column.

Introduction

Although column flotation in copper and molybdenum cleaning circuits was firmly established in 1986, no published information could be found pertaining to a column operating successfully in a zinc cleaning circuit. This fact led to an agreement between the Manitoba MDA and Ruttan mine to study the performance of a pilot flotation column in the Ruttan zinc cleaning circuit.

The project involved the installation of a 36" diameter by 43' high column complete with level, bias, and air control loops to initially treat zinc rougher concentrate. The research work consisted of testing the effects of column level, wash water, air flow, bias control, feed flow rate, frother, etc. on column concentrate grade and recovery. The test work was then repeated using other zinc cleaner products as feed to the column.

Technical Discussion

1. Existing Zinc Circuit and Metallurgy

The zinc circuit consists of two parallel rougher banks followed by two parallel scavenger banks. Each bank is made up of seven Agitair 120A cells (400 cu ft. each). The combined rougher-scavenger concentrate is pumped to two parallel three stage cleaner banks consisting of twelve Denver DR30 (100 cu ft each) cells. The cleaner scavenger concentrate is returned to the first cleaner concentrate while the final cleaner tails is returned to the head of the zinc rougher circuit. (See figure 1)

$CuSo_4$ is added to the copper tails which is pumped directly to the zinc rougher feed. Lime, MIBC, and SAX are added to float the sphalerite at a pH of 11.5. Zinc cleaner pH is typically 10.5 in the first cleaner. Higher pH's in the zinc cleaners generally prove detrimental to concentrate grade. Annual zinc concentrate grades will average 51-52% zinc, 1% copper, and 11% iron with recoveries varying as feed grade fluctuates. Zinc feed grades can fluctuate from 0.5 to 2.5% over as little as a two hour period. Figure 2 shows the approximate relationship between zinc feed grade and recovery.

Tables 1 and 2 show a typical assay size distribution, and mineralogical breakdown of a final zinc concentrate sample. It can be seen from the tables that the main gaungue mineral is pyrrhotite in the -325 mesh fraction. The coarser fractions are generally free and high grade. Micro probe studies also reveal that up to 7% of the iron in the zinc concentrate is in solid solution in the sphalerite.

Table 1 Zinc Concentrate Assay Distribution

Mesh	%Wt	%Zn	%Cu	%Fe	Zn	Cu	Fe
100	0.35	50.7	.45	11.0	0.34	.15	0.4
150	7.35	53.1	.75	9.3	7.5	5.2	6.7
200	24.05	55.2	.65	8.2	25.5	14.7	19.3
270	20.30	53.1	.61	9.7	20.7	11.6	19.2
325	8.45	52.4	1.03	10.3	8.5	8.2	8.5
-325	39.50	49.2	1.62	11.9	37.4	60.2	45.9
Totals	100.0	52.0	1.06	10.3	100.0	100.0	100.0

ZINC CLEANING USING COLUMN FLOTATION AT RUTTAN OPERATION, HBM&S

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ABSTRACT

The effect of column flotation in the Zn circuit has been studied at Ruttan Operation of HBM&S, Leaf Rapids, Manitoba as part of a Ruttan/CANMET/Manitoba MDA Program. A 91.4 cm diameter by 12.5 m high (36" x 41') flotation column was used to clean the combined concentrate from Zn-Rougher and Zn-Scavenger circuit and to reclean the Second Cleaner concentrate. Initial test work produced erratic results due to oversized pumping equipments and control problems. Redesigning column feed and tails discharge systems helped solving the problems. The test results indicated that the zinc concentrate could be upgraded by 4 units to 55% Zn, while maintaining the same zinc recovery as the existing circuit. Encouraged by the successful results, a 213 cm (7') diameter flotation column is being installed to replace the final cleaner stage in the existing zinc circuit.

Table 2 Zinc Concentrate Minerology

Occurance of Sphalerite, %	
Free	90
Middling	10
Locked	0

Mineralogical Composition, %	
Sphalerite	80
Chalcopyrite	3
Pyrrhotite	15
Pyrite	2

2. Pilot Column Installation

The 3' diameter by 43' high column was installed in late 1986 to initially treat zinc rougher-scavenger concentrate. Figure 3 and 4 show the column flow sheet and main features of the column installation. The entire rougher-scavenger concentrate was pumped to a 4' x 5' head tank which fed the column through a 6' line and Magflo meter, controlled by a manual valve. The column tails were pumped through a 6" line and Magflo meter using a fixed speed 5 x4 SRL pump. The tails flow rate was controlled using a 6" pneumatic pinch valve. Column concentrate flowed directly to the final zinc concentrate launder.

Figures 5, 6, 7, and 8 show different views of the original column installations.

3. Flotation Column Control Loops

The column design incorporated three basic control loops;

a) Column slurry level controlling wash water

b) Column tails flow controlled by positive bias to feed flow

c) Air sparger flow manually set using a rotometer

Figures 9, 10, 11, 12 and 13 show the control loop schematics and PID controller configuration.

4. Column Start Up and Test Work

i. Treating Zinc Rougher Concentrate

Initial test work indicated that the column could only upgrade the zinc rougher-scavenger concentrate from 30-35% zinc to 45% zinc. This grade is similar to second cleaner concentrate. As research progressed it became evident that there were some operating and design problems that were hampering proper testing. Badly surging feed pumps caused erratic feed to the column resulting in dramatic pulp level changes and collapsing froth.

Slowing the pumps down did not alleviate the problem. A second concern was the line sizes of the column feed and discharge. The 6" lines were obviously too large to permit low flow rates which were required to properly test the column. The higher flows resulted in more material being recirculated through the cleaners to the point of overflowing pump boxes. A third problem area was in leakage through the filter cloth spargers causing large coalescing bubbles and hence intermittent froth break up.

After several months of trials during which numerous small changes were made to try and improve the feed and control of the column operation, it was decided to modify the circuit to feed first cleaner concentrate to the column.

ii. Treating Zinc First Cleaner Concentrate

After completion of piping changes a series of tests were conducted to treat the first cleaner concentrate. Table 3 shows % zinc, copper and iron in the column feed, concentrate, and tails.

Table 3 Column Test Results for First Cleaner Concentrate

Feed			Conc			Tail		
Zn	Cu	Fe	Zn	Cu	Fe	Zn	Cu	Fe
45	3.2	15.7	54	1.6	8.6	38	5.8	17.9
40	5.6	17.4	52	1.7	8.4	39	4.7	17.2
42	5.0	17.5	52	1.7	8.4	45	3.2	15.1
38	3.4	19.7	57	1.2	8.9	41	0.8	19.1
36	4.3	21.0	51	1.5	10.0	37	4.2	21.1
41	3.5	18.9	50	1.3	10.2	41	3.6	18.7
34	5.5	20.4	51	1.3	10.6	30	7.0	21.6

Results indicated that the column was able to produce a higher concentrate grade than the existing three stage cleaning. Recovery, however was low and ranged only from 10 to 40%. The problems treating the first cleaner concentrate were similar to those that occured when treating the rougher concentrate, mainly erratic and uncontrolable feed rates.

During this period of test work the cloth spargers were replaced with a commercial rubber sparger. The new sparger appeared to reduce the 'boiling' effect that often disrupted the froth column, contributing to poor recoveries. Also, during this period the effect of frother injected into the wash water was tested. The use of small amounts of frother produced a more stable froth allowing a deeper froth column to be maintained.

5. Column Circuit Redesign

After a period of inactivity on the column project due to personnel changes and other priorities, a decision was made to recommission the column. In reviewing previous test work and existing circuit data the column feed and discharge arrangements were redesigned. The changes were based on equations proposed by Dobby and Finch in their "Column Flotation Manual"

The circuit was designed to initially treat zinc final concentrate. The design feed flow rates to produce a column concentrate grade of 54-55% zinc at recoveries similar to the existing three stage circuit were in the order of 30-40USHPM. The low flow rates required the down sizing of the column feed and discharge lines from 6" to 3". Other changes made to control column feed and discharge were;

a) replacement of 5x5 SRL column head tank feed pump with a 3x3 SRL pump.

b) replacement of column discharge pump with a 3" pneumatic pinch valve and mechanical positioner. (gravity flow discharge)

c) installation of a pneumatic pinch valve or the column feed to control flow rate

d) installation of an agitator on the column feed head tank

6. Test Work on Recommissioned Column

The purpose of the test work was threefold;

1) to determine optimum column operating parameter values (ie. froth depth, frother, feed tonnage, bias, etc.) for each application;
    a) 3rd clnr Zn conc. feed
    b) 2nd clnr Zn conc feed
    c) Zn Rougher-Scavenger conc. feed

2) to use this data in sizing a plant scale column

3) to use this data in an economic comparison of column performance to hot reverse flotation technology.

The column pilot unit was fed three different process streams over the test period;

1) 3rd clnr Zn conc. feed

2) 2nd clnr Zn conc. feed

3) Zn Rougher-Scavenger conc. feed

Figure 14 shows a basic schematic of the column set up.

The column was run over eight, twelve hour, shifts and sampled continuously over these periods. The conventional cells were also sampled for comparison purposes.

The samples were then taken to the lab where percent solids determination and metal assays were completed.

Results and Discussions

The testing was completed in three phases (ie. third cleaner feed, second, etc.). The results of each will be analyzed seperately. Before the analysis of the data, some general operating observations and characteristics of the column cell will be discussed.

Column Control

The process control scheme (figures 15, 16, 17) that was employed on the column is;

a) very simple
b) easily adapted to computer control
c) has the capability of performing extremely well

Point c above is stated in this manner due to a few difficulties that were encountered. These difficulties are explained below as are the solutions.

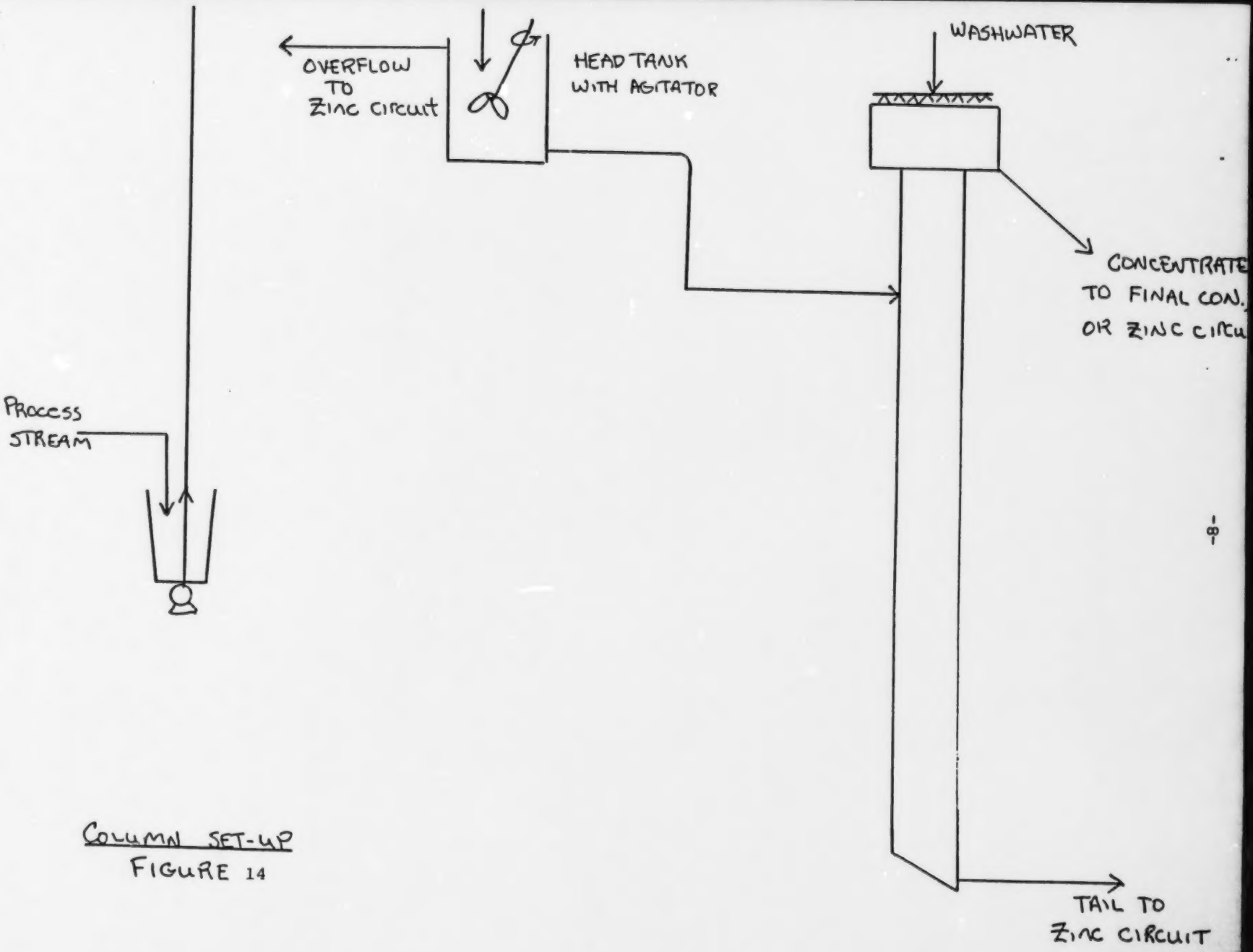
The level control was the most troublesome. This problem can be explained by a contribution of;

a) faulty wash water control valve
   At times the control valve would stick, causing the level to vary from the set point. Manual adjustments were then made to keep the level at set point.

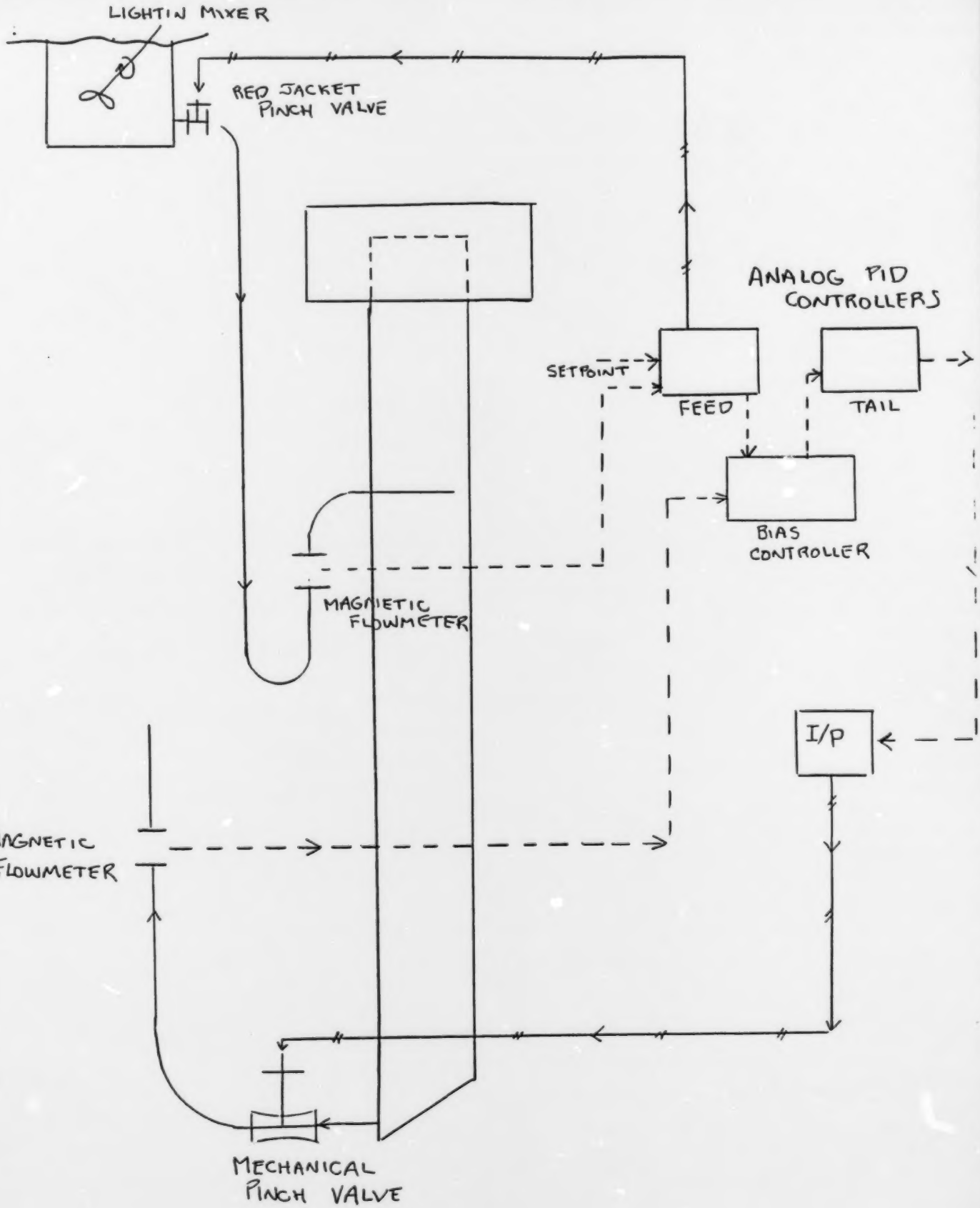
b) variations in wash water line pressure
   If wash water line pressure dropped significantly the level would vary from set point. This drop in line pressure was caused by water demand on lower floors (ie. hosing) which are supplied by the same line.

c) insufficient frother in the feed
   If there was a lack of frother in the feed the column could not achieve a nice deep stable froth. It was observed that when the copper or zinc circuits were fed higher doses of MIBC on shift the level would be fine. An extra 10-20cc/min on either circuit was enough to do the trick.

d) feed density lower than 15% solids
   When the feed density decreased below 15% solids the froth would become very feeble. The absence of sufficient frother contributed to this fact also.

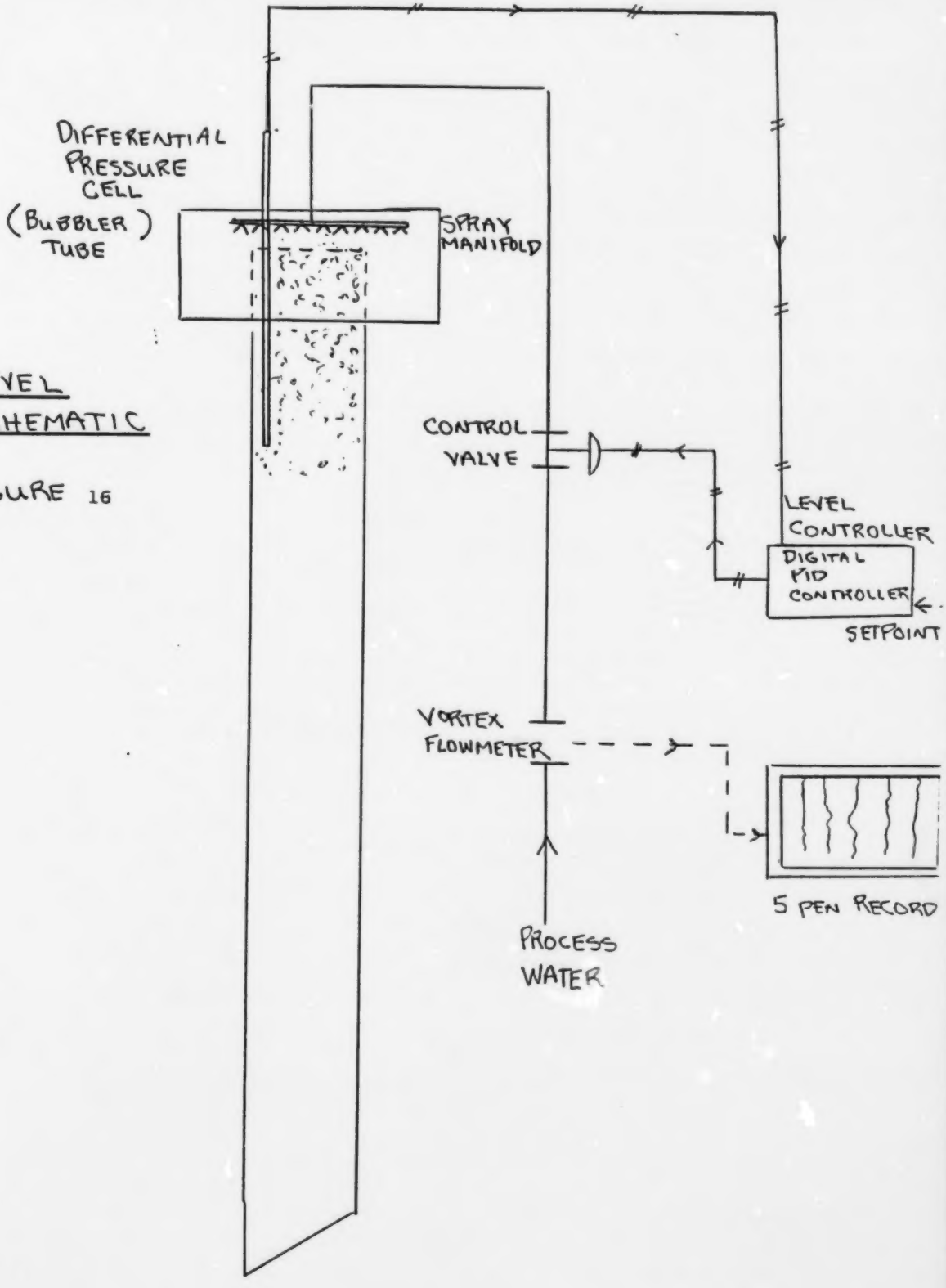


COLUMN SET-UP
FIGURE 14



COLUMN BIAS
CONTROL SCHEMATIC

FIGURE 15

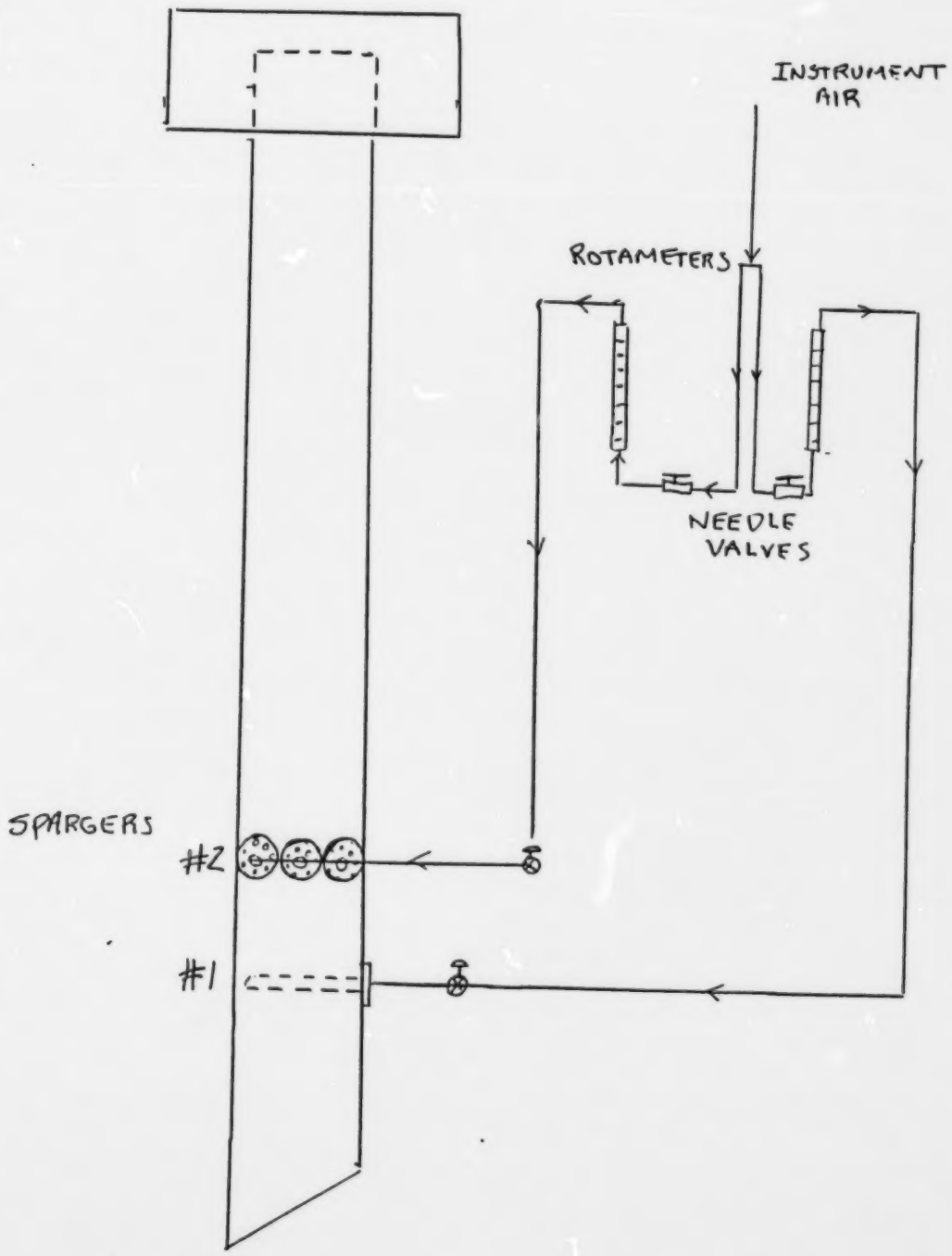


COLUMN LEVEL CONTROL SCHEMATIC

FIGURE 16

COLUMN AIR SET-UP

FIGURE 17



The level problem was intermittent. In some test runs there were no problems at all, but at times problems did occur and the previously described observations were made.

Another problem encountered was that there was no limit placed on the tailing flow rate. At times when the feed would approach a low flow condition the tails would follow due to the effect of the bias controller. This would cause the tail line to sand due to low flow or velocity within the line. The occurrence of a low flow condition was generally caused by an excessive percent solids in the feed. As the percent solids exceeded 60% the tail line had a tendency to sand.

These operating and control problems were overcome with a few simple changes;

1) dedicated wash water line
2) wash water control valve in good working order
3) extra 10-20 cc/min MIBC on circuit at times
4) low limit placed on tails flow rate
5) density control on feed to column

Column Operation

Other than the problems described above, the operation of the column was very straight forward.

The air was set manually and the set points for level, feed and bias input into the controllers.

As the controllers had not been tuned since their initial installation (1986) the feed and tails would surge at 30%. The column responded very well to these disturbances showing no ill effects in performance. This proved that a properly sized column may be run in an actual plant setting.

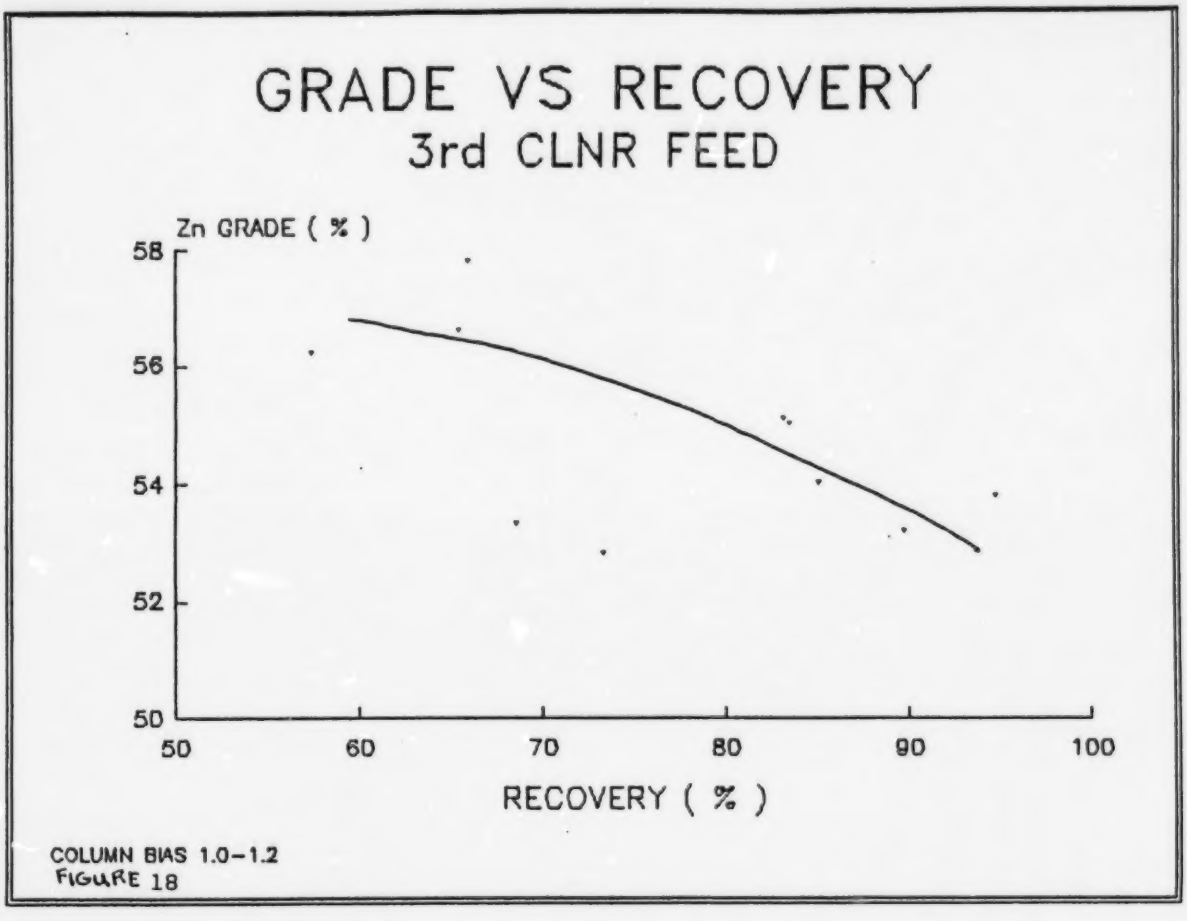
The column cell was very similar to a conventional cell in operating philosophy. The harder it is pulled the greater the recovery, while pulling slower allows grade to be maximized. This similarity will allow a good flotation operator to catch on quickly to the way a column operates. Also, the flexibility of a column contributes to its superiority over conventional cells as bias, level (ie. wash water addition) and air rate may be varied to obtain optimum results.

Third Cleaner Zinc Concentrate Feed

The column cell was employed as a recleaner (ie. 4th cleaner) in the first phase of column testing.

Figure 18 illustrates the columns grade-recovery relationship.

Upgrades between 3.0-6.6% zinc were obtained. Copper and iron rejections varied between 11-70% and 40-94% respectively.



COLUMN BIAS 1.0-1.2
FIGURE 18

Optimum parameter values were found to be;

Level - 1.0-3.0 ft
Bias - 1.0-1.2
Superficial wash water velocity - 0.10-0.30cm/s (0.825cm/s Max)
Superficial air velocity - 2.5-3.5cm/s (4.4cm/s max)

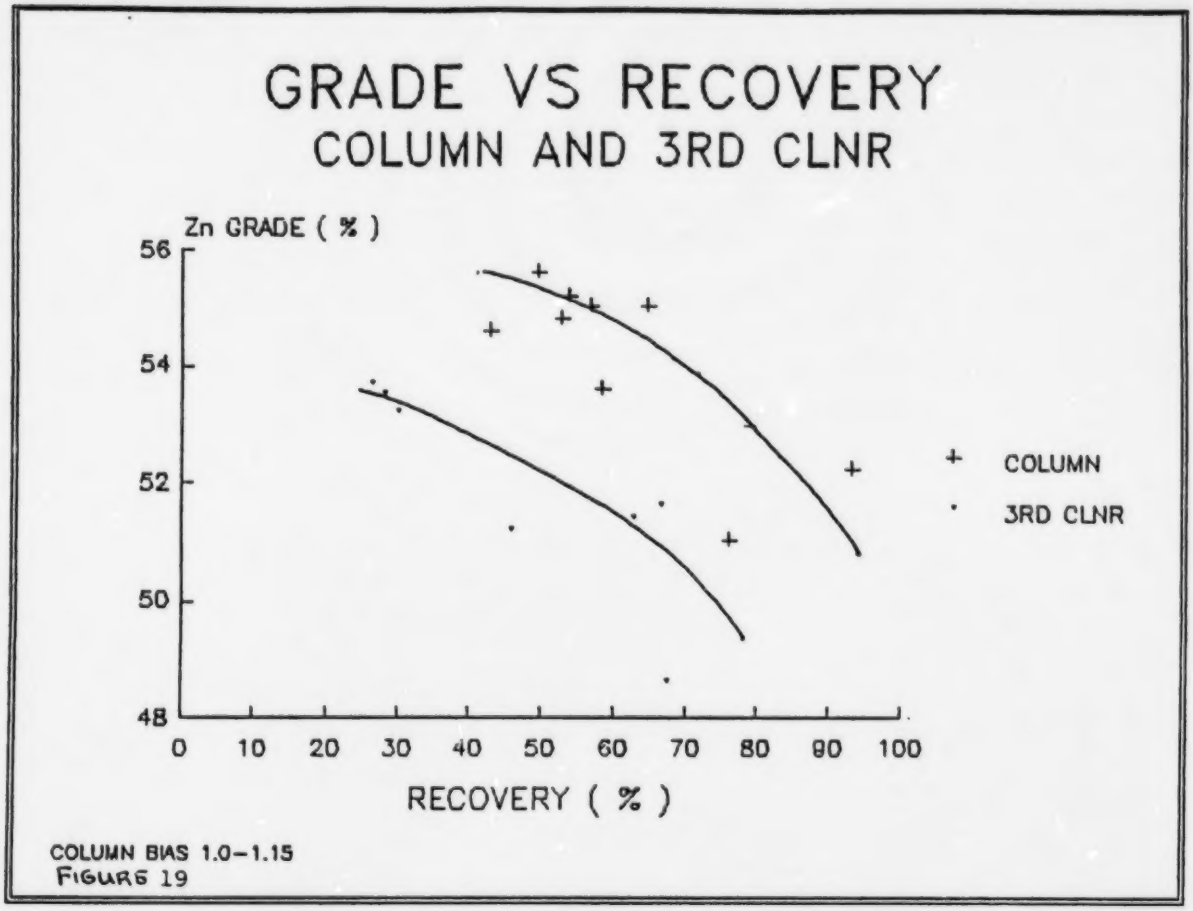
** Sizing calculations indicate that a plant scale column would have the following dimensions: Diameter 6', Height 45' with the following air and wash water requirements: Air 140-200 SCFM (max capacity 250 SCFM), Wash water 40-125 USGPM (max capacity 350 USGPM)

Second Cleaner Zinc Concentrate Feed

In this phase of the testing the column's performance was compared to the third zinc cleaner cell.

As can be seen in figure 19 the column definitely outperformed the conventional third cleaner cell.

Column upgrades between 5.0-17.3% zinc as compared to third cleaner upgrades of 3.8-9.4%. Copper and iron rejection varied between 26.2-91.1% and 30.8-81.3% respectively.



COLUMN BIAS 1.0-1.15
FIGURE 19

Optimum parameter values were found to be;

Level - 2.0-4.0 ft
Bias - 1.0-1.15
Superficial wash water velocity 0.097-0.485
Superficial air velocity - 2.0-3.5cm/s (4.4 Max)

**Sizing calculations indicate that a plant scale column would have the following dimensions: Diameter 7', Height 45' with the following air and wash water requirements: Air 152-270 SCFM (350 SCFM max), wash water 55-275 USGPM (max 500 USGPM)

Rougher-Scavenger Concentrate

The purpose of this testing was to compare the column cell to the cleaner-scavenger, first cleaner and second cleaner cells.

Figure 20 illustrates the comparison.

Column upgrades between 10.0-28.3% zinc were realized while the conventional cells upgrades varied between 7.2-25.0%.

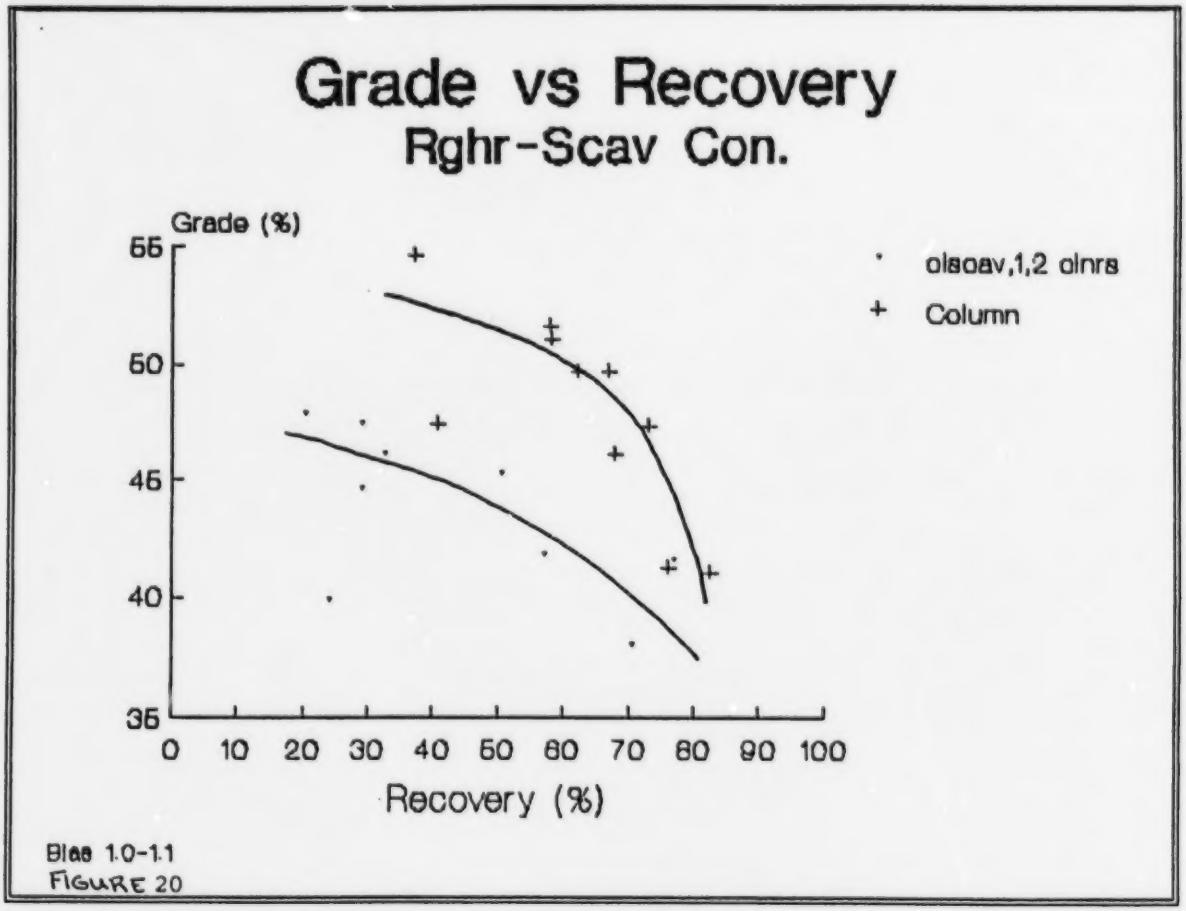


FIGURE 20

The column operating parameters were set as follows;

Level - 0.8-1.0 ft
Superficial wash water velocity - 0.07-0.5cm/s
Superficial air velocity - 3.3-4.3cm/s

**Sizing calculations will have to be done when a larger database of zinc circuit surveys has been completed.

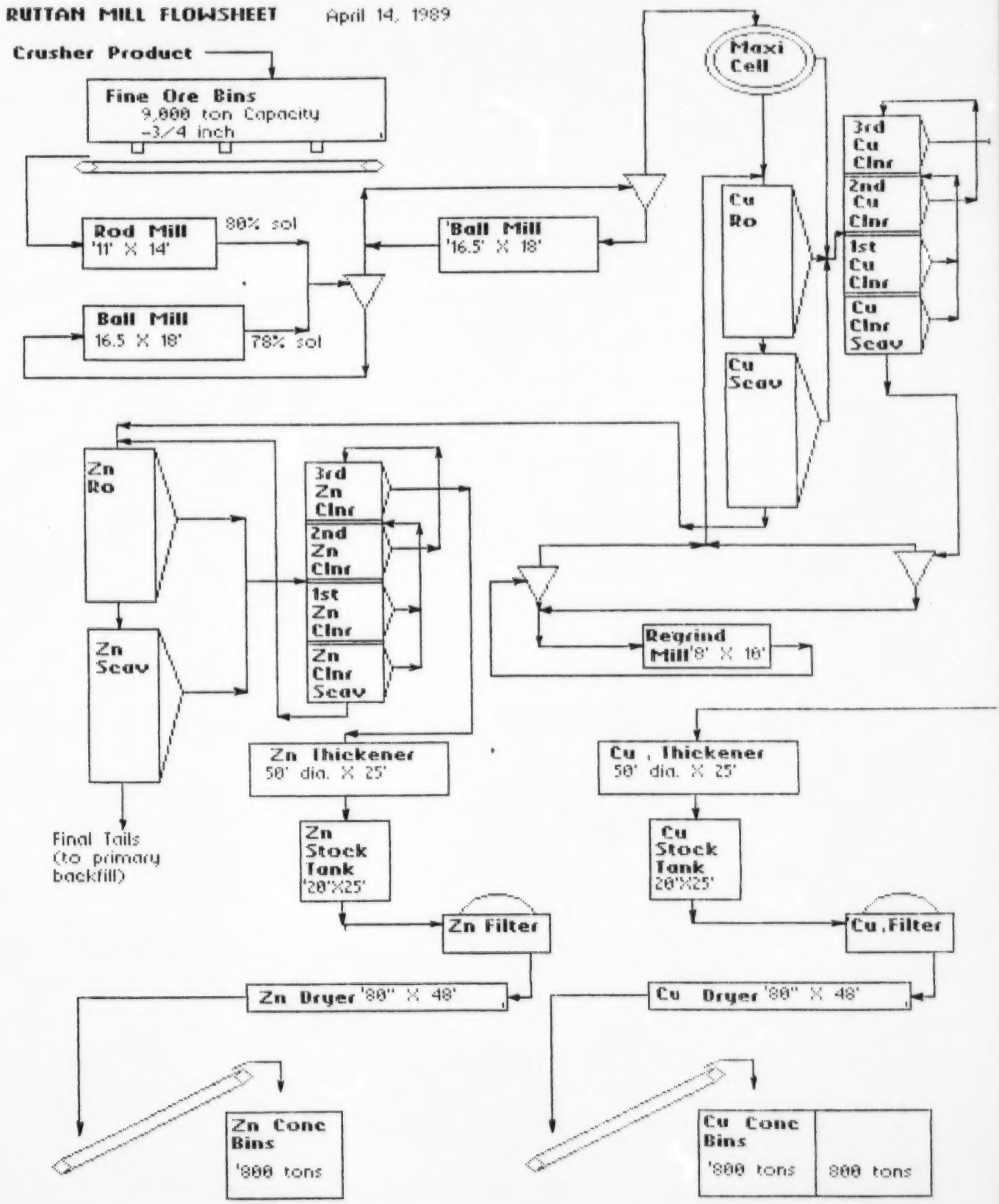
Preliminary numbers used indicate that a single 13' diameter column would be required.

Conclusions

1. The pilot column outperformed the conventional cleaner circuit in both concentrate grade and recovery. A comparison between the column and existing final cleaner cells when treating second cleaner concentrate indicate that the column can produce a concentrate grading 4% units of zinc higher than the existing cells for the same recovery.

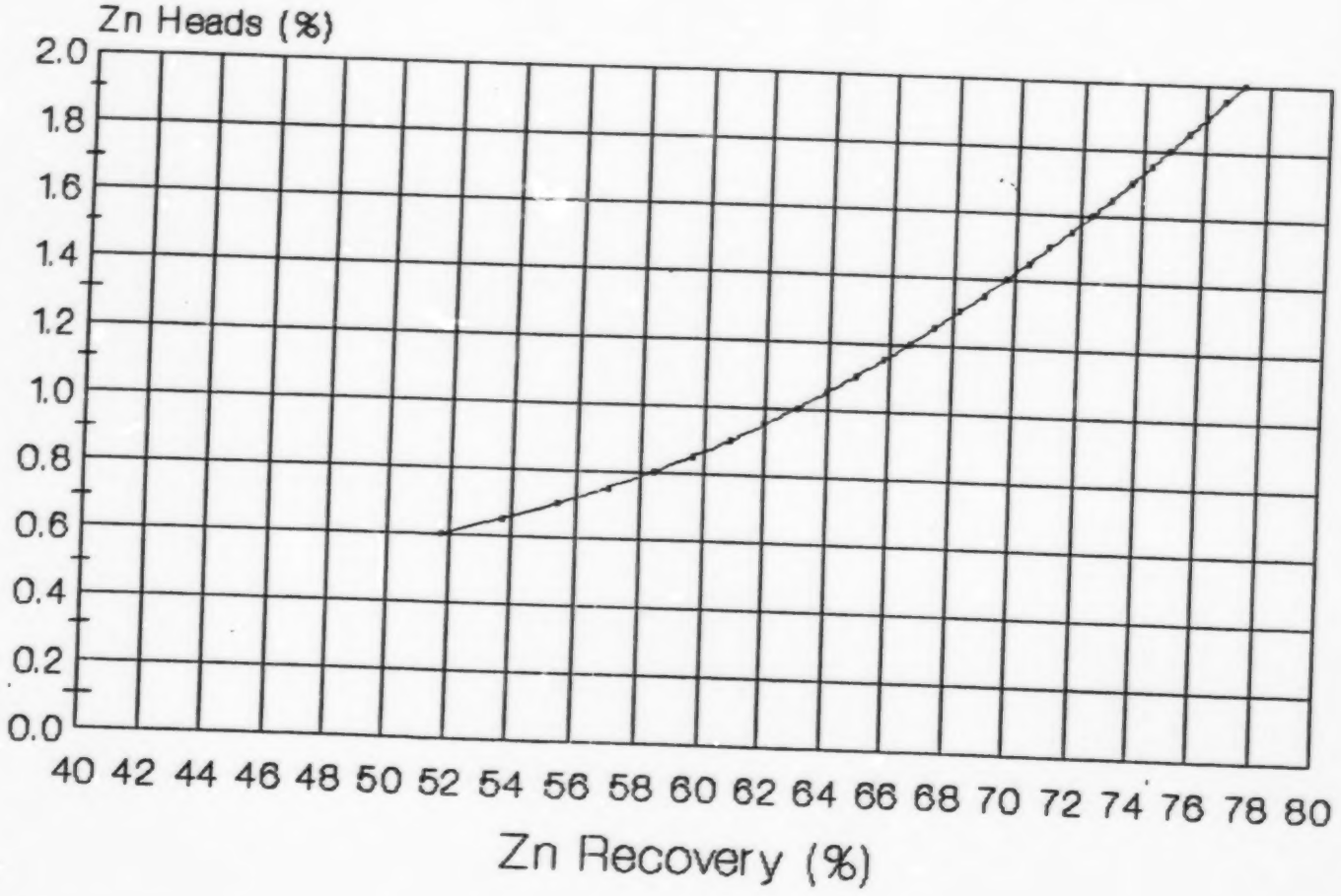
2. The operating strategy for the column using bias and level wash water control loops with air controlled manually worked well.

Zinc Circuit Flowsheet - Figure 1

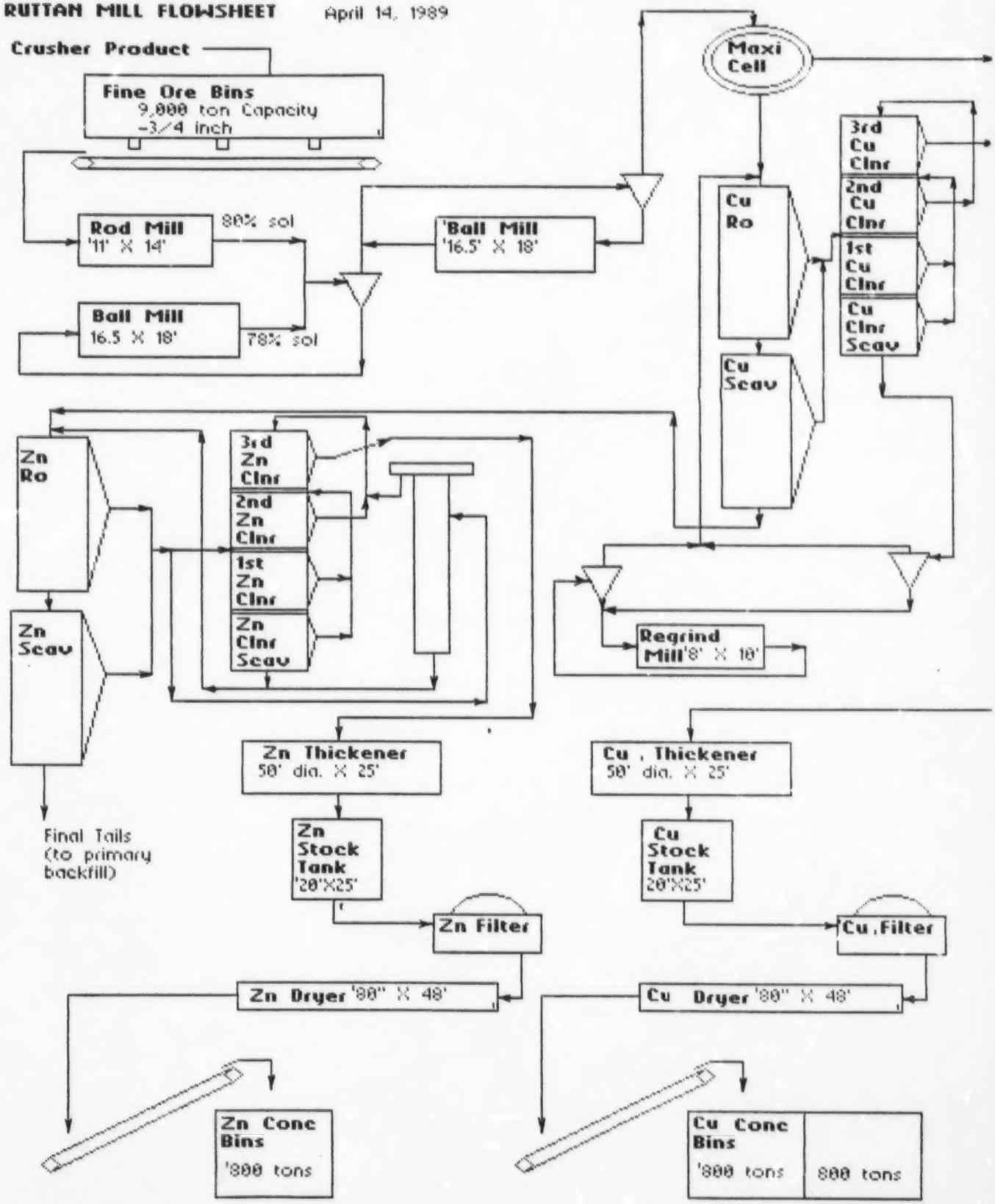


RUTTAN MILL

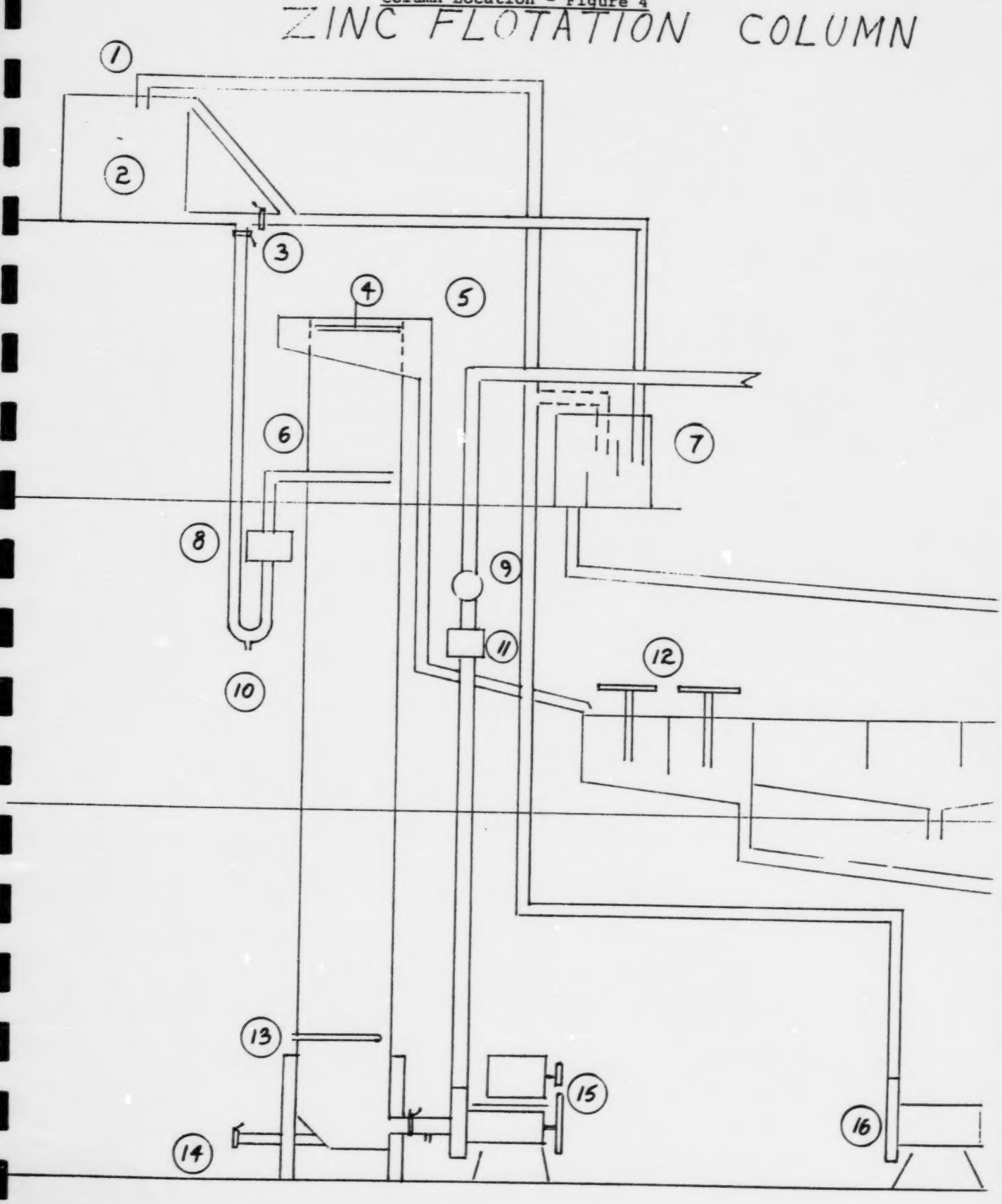
Zn Heads Vs Zn Rec.



Column Flowsheet - Figure 3

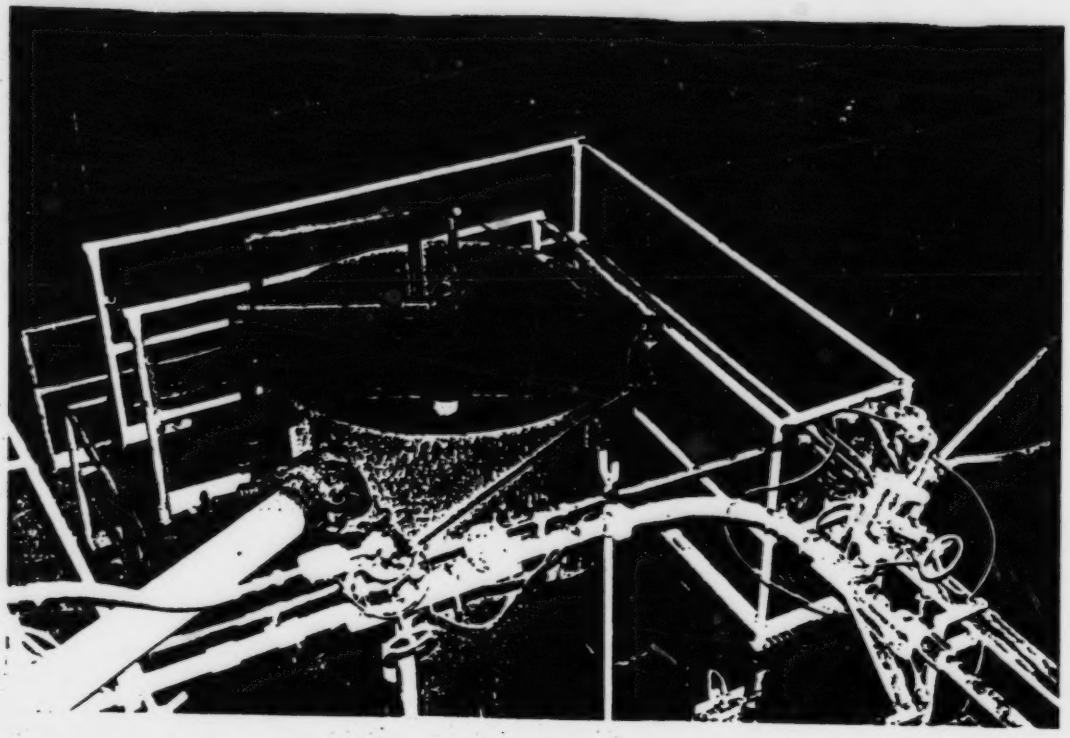


Column Location - Figure 4

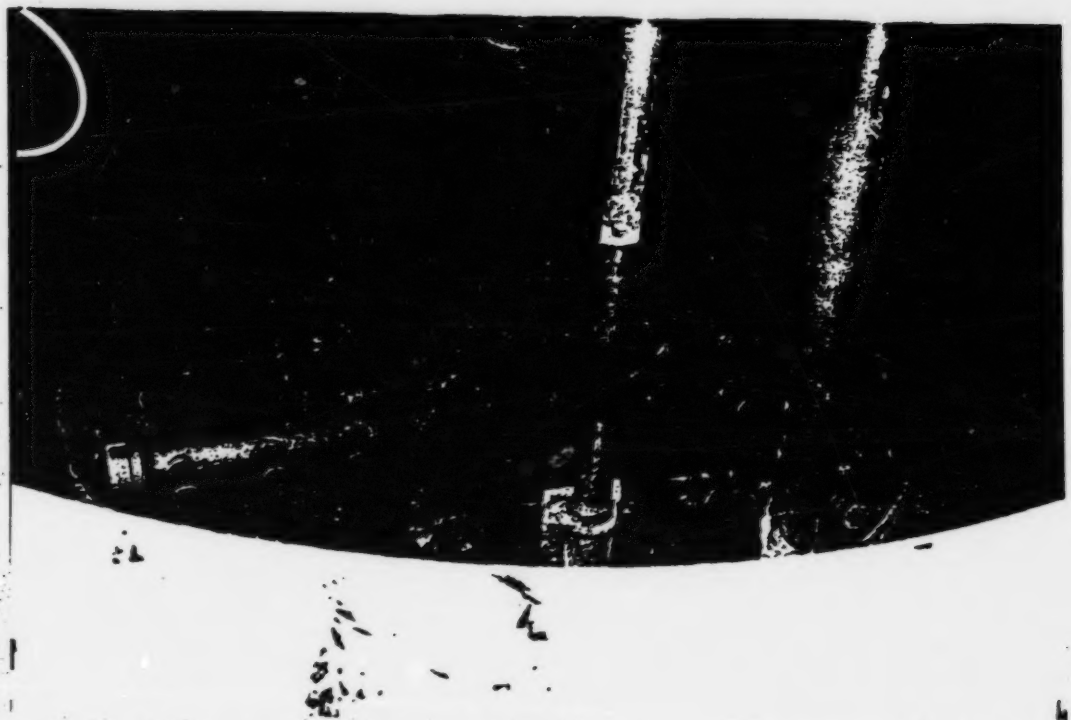


Column Launder and Wash Water Assembly
ZINC FLOTATION COLUMN

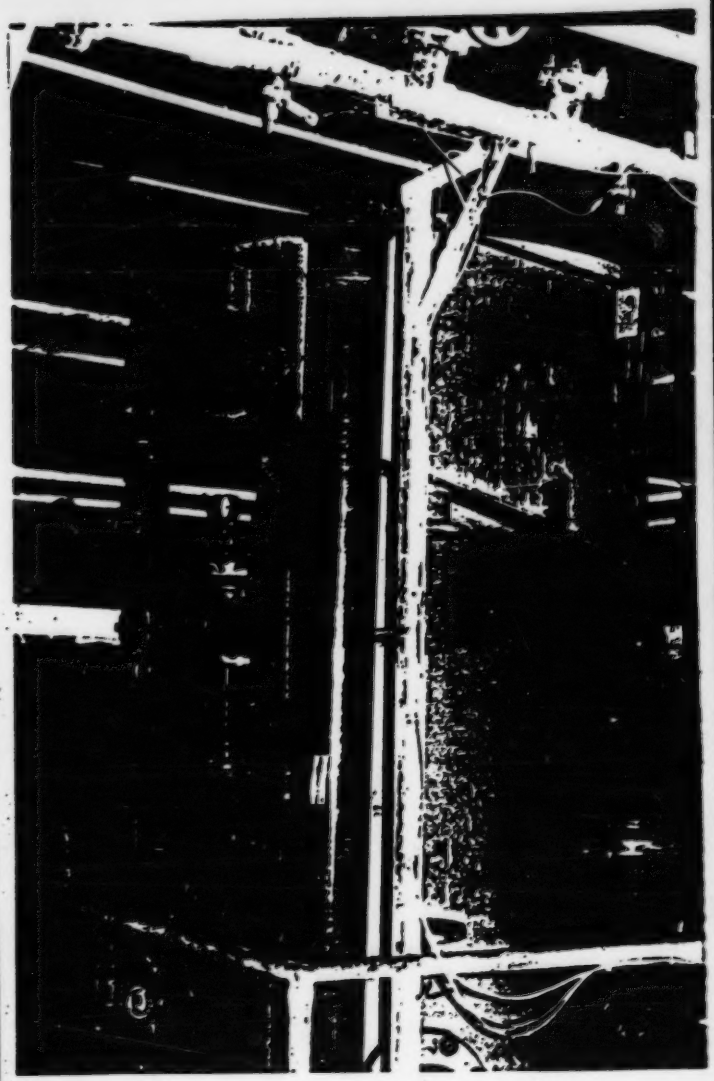
1. MIBC addition to feed tank. Two way valve at MIBC head tank.
2. 4'x5' feed head tank.
3. Shut off and by pass valves.
4. Spray wash water manifold with MIBC addition injection valve.
5. Air control valves and flowmeter.
6. Wash water automatic valve and flowmeter. Manual by pass valves.
7. Zn cleaner distribution box.
8. Column feed mag flowmeter (6").
9 Column discharge red jacket control valve.
10. Feed drain valve.
11. Column discharge mag flowmeter (6").
12. Zn cleaners.
13. Air bubblers.
14. Column drain valve.
15. 5x4 SRL-C discharge pump.
16. PH20 (Zn Rougher-Scavenger conc.).



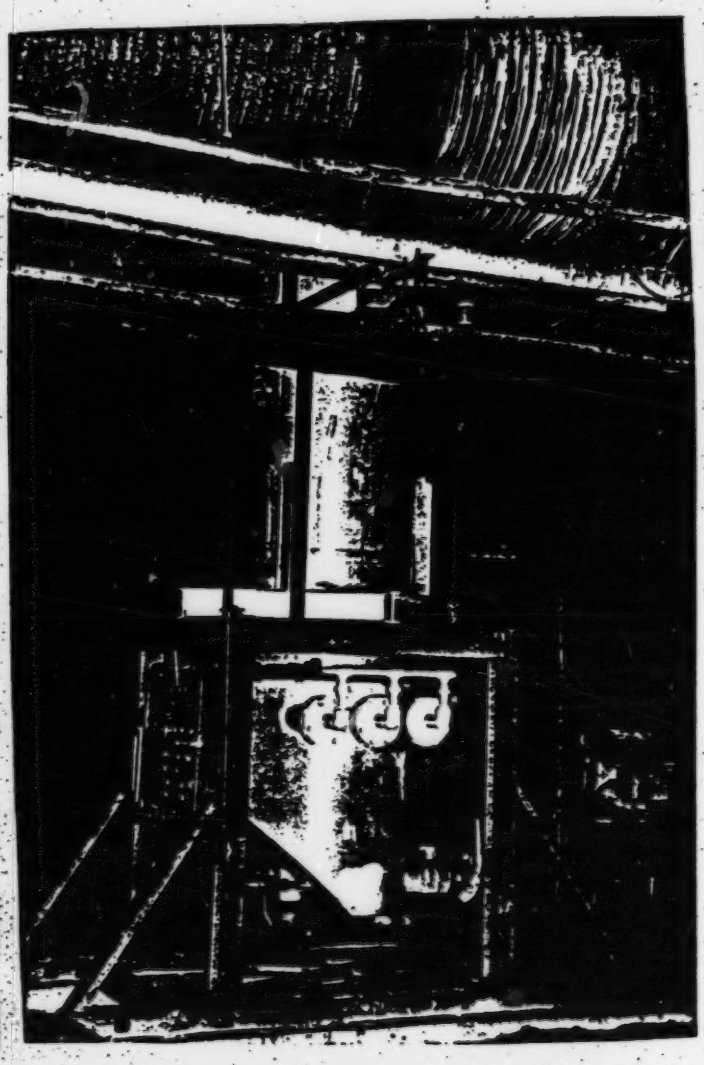
Column launder and Wash Water Assembly - Figure 5



Column Wash Water Manifold - Figure 6



Column Wash Water Valve Assembly - Figure 7

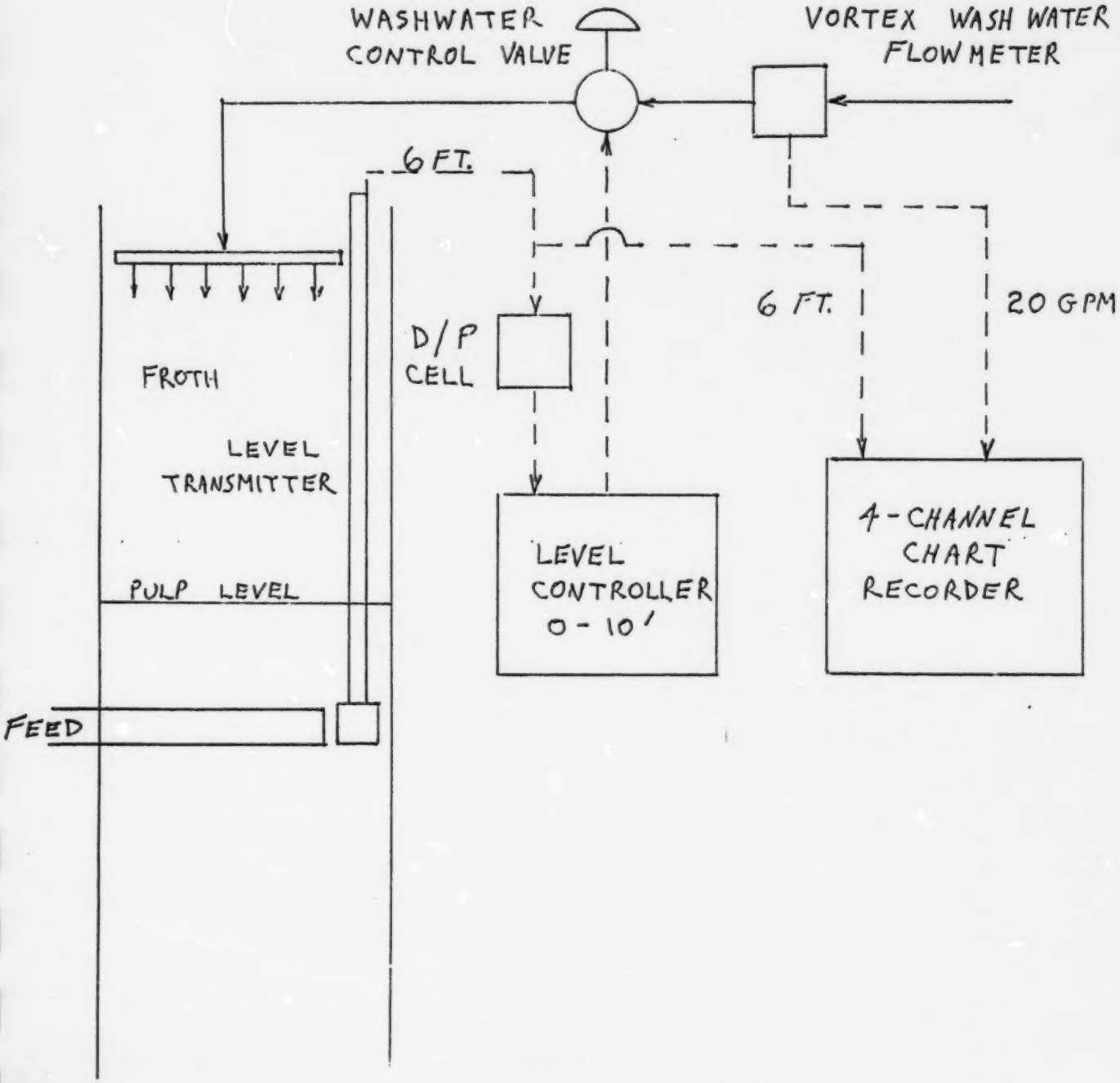


Column Sparger and Air Flow Assembly - Figure 8

ZINC COLUMN FLOTATION

Pulp Level Control Loop - Figure 9

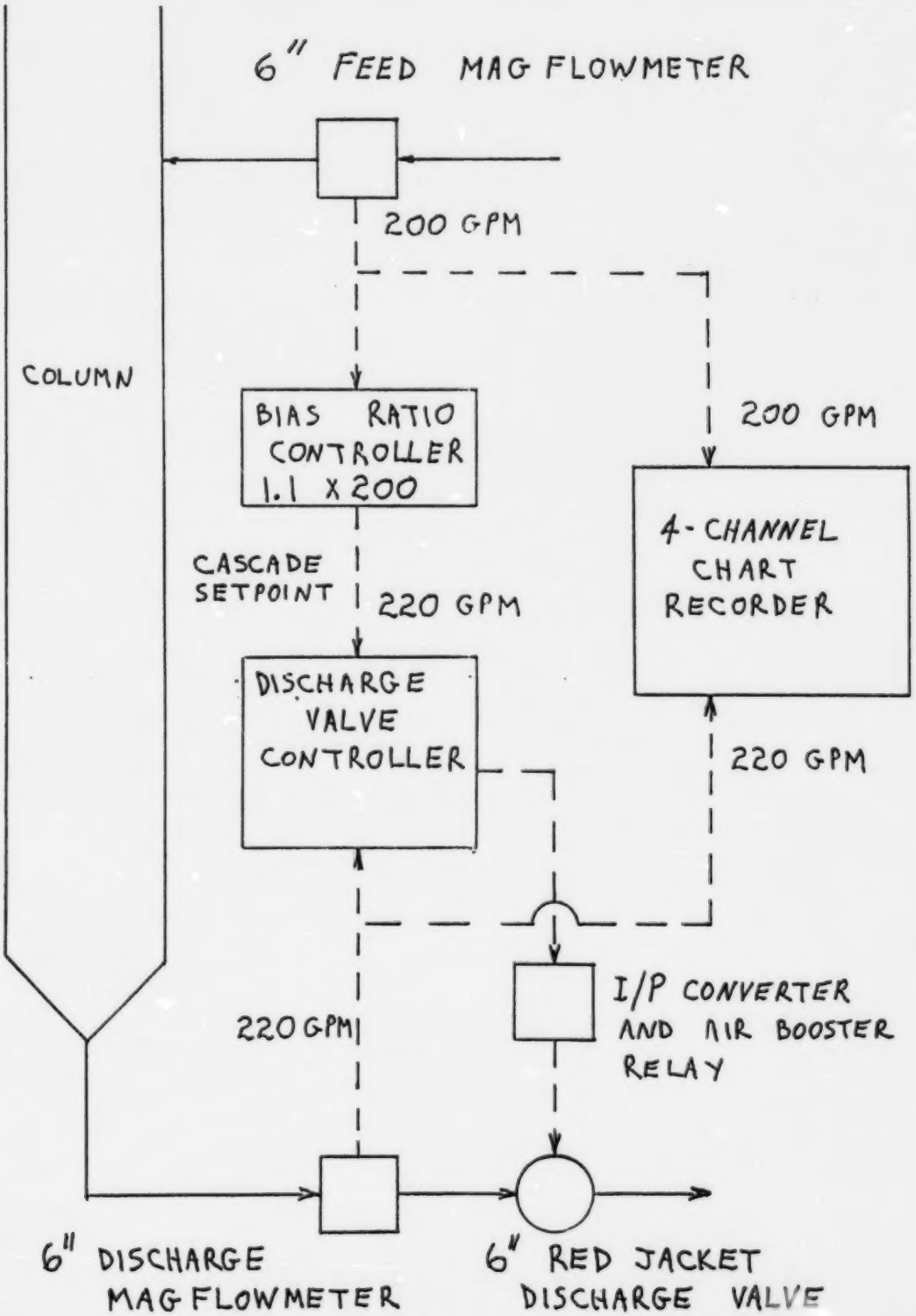
PULP LEVEL CONTROL LOOP



ZINC COLUMN FLOTATION

BIAS CONTROL LOOP

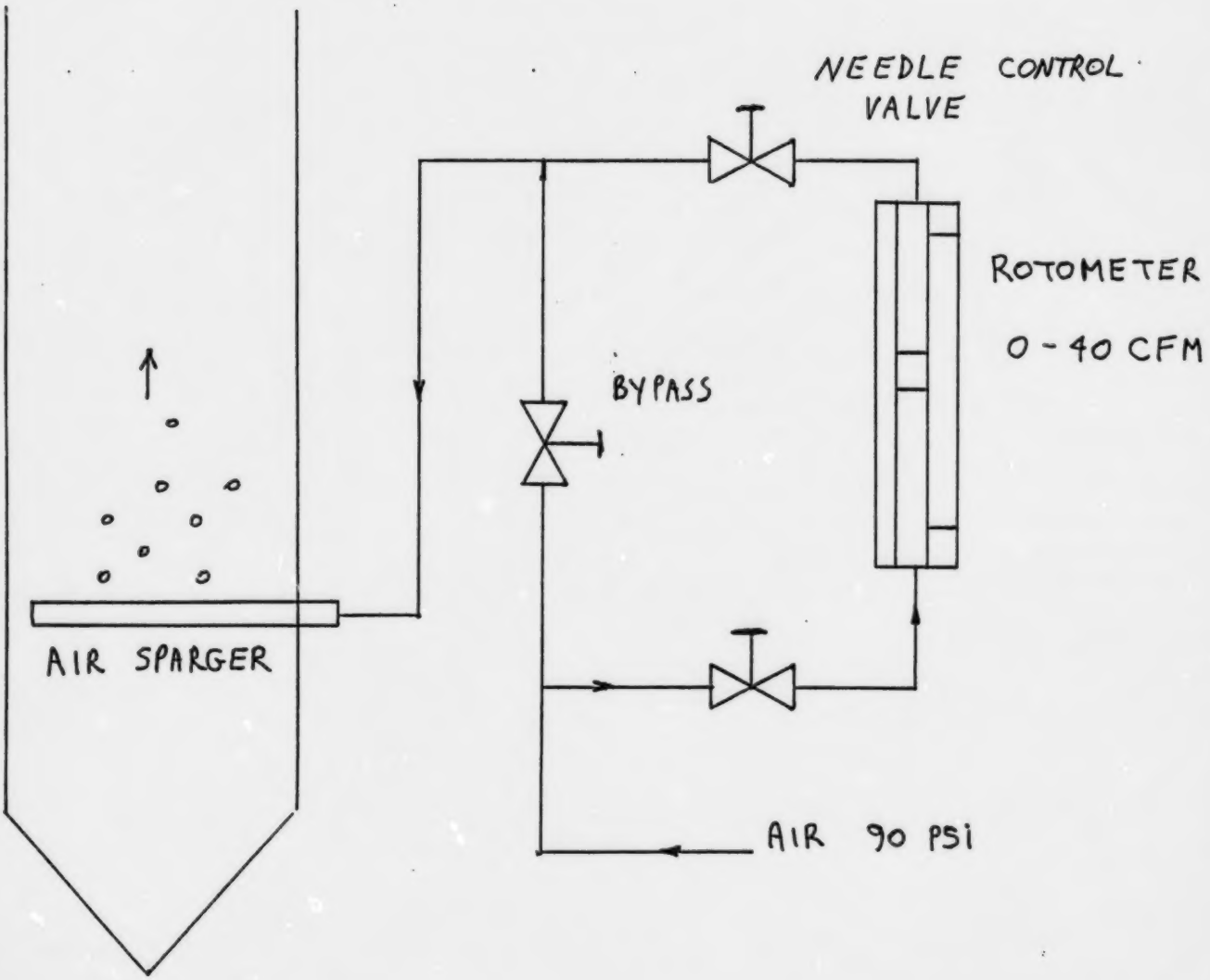
Figure 10



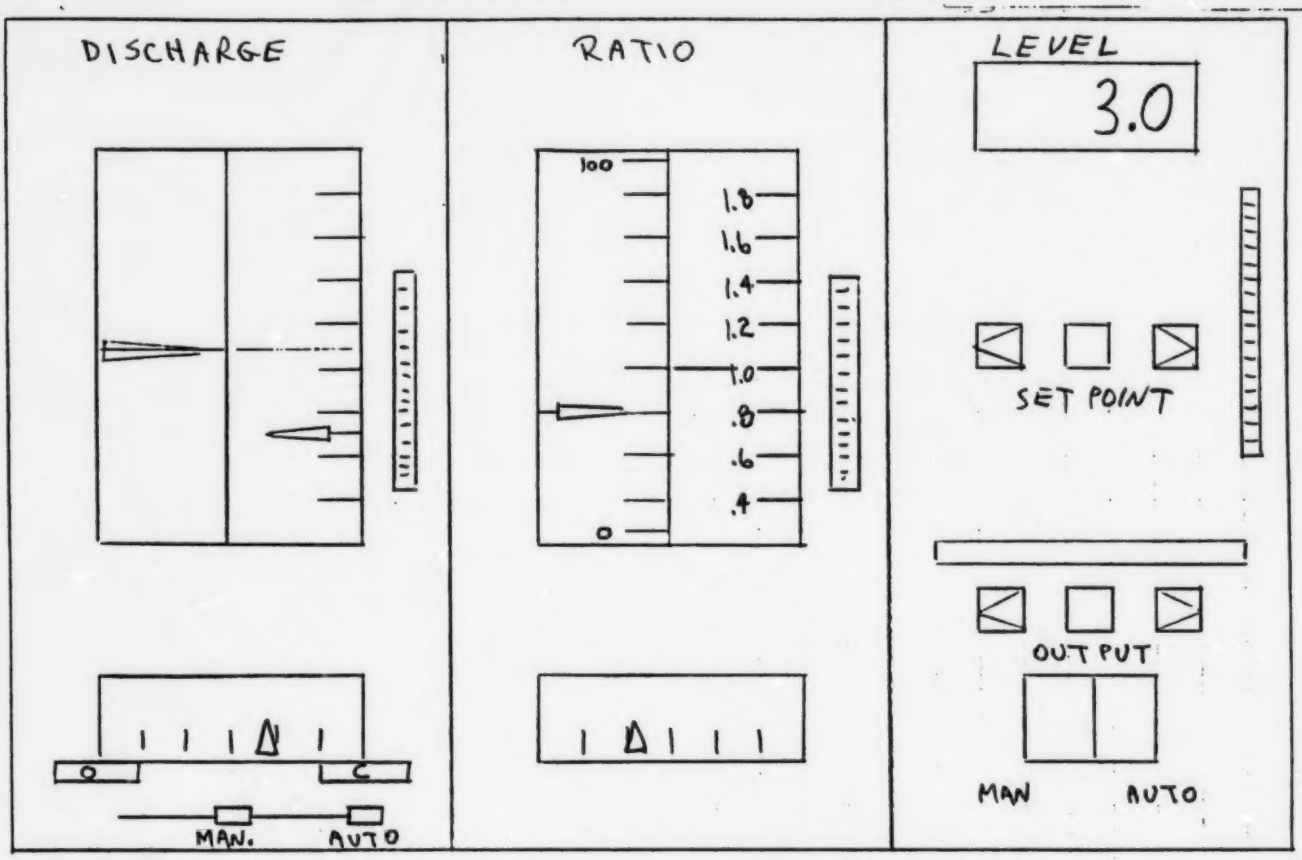
ZINC COLUMN FLOTATION

Sparger Air Control System - Figure 11

AIR CONTROL LOOP



PID Controllers for Control Loops - Figure 12



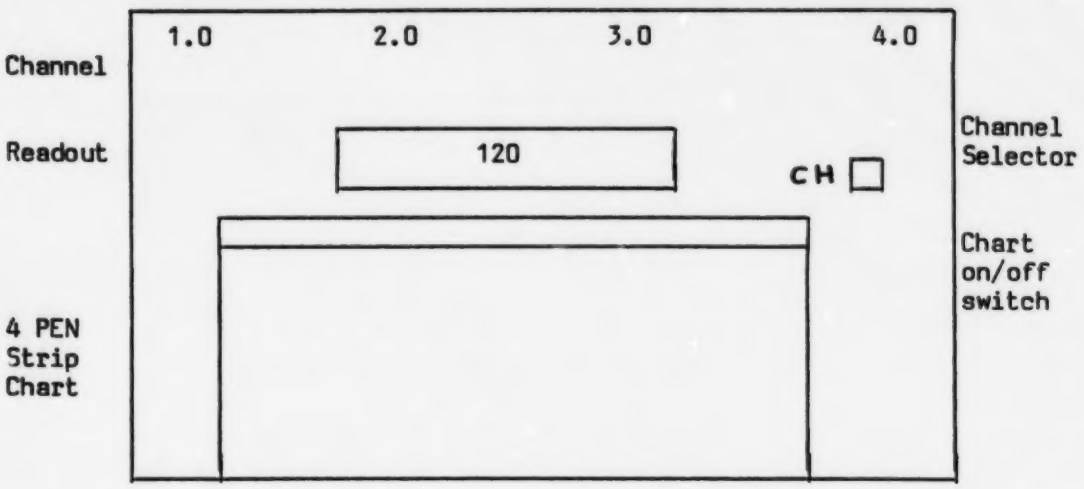
1. Discharge controller controls the column discharge red jacket valve. In auto mode it receives a set point from the ratio controller. On start up it should be on manual with the valve on 3/4 closed. When the discharge pump is started the discharge volume should be manually adjusted to equal approximately the feed volume, then switch to auto.

2. The ratio controller multiples the feed volume by the ratio set point and outputs (cascades) a setpoint to the discharge flow will follow changes in feed flow. The ratio setpoint should be adjusted such that discharge flow is 5 - 15% higher than the feed flow. The difference is made up of wash water.

3. The level controller controls wash water to maintain the setpoint level. It should be on manual and valve half open until desired level has been reached. It then can be switched to auto.

4 Channel Recorder for Column Variables - Figure 13

CHANNEL #	PEN	RANGE
1. Feed Flow	Red	0-1000 gpm
2. Disch. Flow	Green	0-1000 gpm
3. Water Flow	Blue	0-150 gpm
4. Pulp level	Black	0-10 ft



The 4-PEN chart recorder monitors column feed and discharge flows (GPM), spray water flow (GPM), and pulp level (FT). NOTE: The pulp level range is 0-10 ft wtih 0 ft being the concentrate overflow lip.

Instantaneous readings can be obtained for the four variables by pushing the channel buttom marked CH.

INSTRUMENTATION LOOPS

1) - measure feed flow and keep within specified range

2) - using feed flow and a ratio controller keep tails flow as specified:

ie. T/F = 1.4 - 1.5

3) - differential pressure cell to measure froth height. Control of froth height based on wash water addition. To be kept in 3' - 5' depth range. (~30 - 65 USGPM)

4) - air rotameters calibrated as manual adjustments will be made to determine optimum flow. (~20 - 40 SCFM)

PLANT COLUMN FLOTATION THEORETICAL CALCULATIONS

Theoretical Data

Feed Characteristics

260 tph 1% Zn Head
72% Overall Recovery
(Conventional Cells)

∴ 3rd CLNR CON. = 3.74 tph @ 50% Zn
Assume 30% Solids
@ = 1290 kg/m³
Slurry Flow: 43 USGPM

Product Requirement

a) 50% Recovery @ 55% Zn
b) 70% Recovery @ 54% Zn
c) 90% Recovery @ 54% Zn

Air Rate; 20 - 40 SCFM
Washwater; 30 - 65 USGPM

Column Area Calculations

$$Ac = \frac{1.18 \times 10^{4}\ wdb}{Jg * e_p\ d^{2}_{o}}$$

a) 50% Recovery

$w_.$ = 1.7 tph
J_g* = 2.19 cm/s
d_b = 0.3 cm
d_{so} = 104 um

$$Ac = \frac{1.18 \times 10^4 (1700) (0.3)}{2.19 (4.2) (104)}$$

$Ac = 6300\ cm^2$

(1) 36" CIRCULAR COLUMN

b) 70% Recovery

w = 2.42 tph

All other variables as before

$$Ac = \frac{1.18 \times 10^4 (2420) (0.3)}{2.19 (4.2) (104)}$$

$Ac = 9000\ cm^2$

(2) 36" CIRCULAR COLUMNS

c) 90% Recovery

w = 3.12 tph

All other variables as before

$$Ac = \frac{1.18 \times 10^4 (3120) (0.3)}{2.19 (4.2) (104)}$$

$Ac = 11600\ cm^2$

(2) 36" CIRCULAR COLUMNS

CALCULATIONS

COLUMN CROSS-SECTIONAL AREA

Milling 260 tph @ 1.5% Zn
72% Conventional Cell Recovery
3rd CLNR Zn, Con; 5.62 tph @ 50% Zn
30% Solids

Product Requirements
90% recovery @ 54% Grade
∴ 4.68 tph @ 54% Zn

$$A_c = \frac{1.8 \times 10^4 \, (w) \, d_b}{e_p \, d_{80} \, J_g^*} = \frac{1.18 \times 10^4 \, (4680) \, (0.3)}{4.2 \, (104) \, (2.19)}$$

e_p: particle s.g.
d_{80}: cummulative 80% passing particle size (nm)
J_g^*: Superficial gas rate ($cm/_s$)
d_b: Bubble diameter (cm)
w: column product (kg/hr)

∴ $A_c = 17{,}331 \ cm^2$

36" column;	6500 cm^2
48" column;	11600 cm^2
Total	18,100 cm^2